MODEL FARM PONDS WITH AUTOMATED MONITORING OF WATER QUALITY

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ILLUSTRATIONS

MODEL FARM PONDS WITH AUTOMATED MONITORING OF WATER QUALITY

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ABSTRACT

Twelve model farm ponds were built to study the effects of various agricultural practices on the quality of pond waters. Each pond was constructed of glass-coated steel silo sections set on a concrete base and has a capacity of about 70,000 l. The water-quality monitoring system automatically measures and records temperature, pH, and dissolved oxygen by time of day. Measurements are taken by sondes (sensor packages) containing a thermistor, a combination pH electrode, and a conventional polarographic oxygen electrode. Sondes are supported by a cable and lowered to specified depths electronically by a winch activated by phototransistors. A logger records data from signal monitors that display readouts from the sensors. The logger can be interfaced with compatible data-processing systems. The model ponds have not yet produced enough data for a detailed analysis of the diurnal changes in water quality. Operation of the system has been satisfactory. **KEYWORDS: agricultural waters, automated water analysis, model ponds, ponds, water analysis, water pollution.**

INTRODUCTION

Because farm ponds vary widely in their chemical and physical characteristics, it is virtually impossible to adequately replicate, control, and measure important water-quality variables. The high cost of equipment and labor may prohibit intensive monitoring of widely separated ponds, and it may be impossible to find cooperators if proposed research involves potentially hazardous chemicals or undesirable treatments. To overcome such limitations, the Agricultural Water Quality Management Laboratory built 12 model ponds to study the effects of various agricultural practices on the quality of pond waters (fig. 1).

Current research in the ponds includes the cycling of fertilizer phosphorus between the sediments, aquatic plants, and the water; aquatic biology; basic oxygen-exchange coefficients between the ponds and the atmosphere; and primary pond productivity.

This report is designed to give a generalized description of the model ponds and the water-quality monitoring system, together with a simple example of available data. Detailed information, including plans and schematics for the installation, can be obtained from the authors.

MODEL FARM POND

Pond Site and Earthwork

The pond site was excavated to provide a stable and suitable pond environment (fig. 2). Each pond is approximately 6 m in diameter and 2.8 m deep, and each will hold about 70,000 l (fig. 3). Three soil drainage lines, one of which is shown in figure 3, were installed in a 30-cm-thick sand pad beneath the pond bottoms to prevent possible

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flotation of the tanklike units during periods of high rainfall.

Glass-coated steel silo sections (A. O. Smith) were used for the pond sidewalls because of their relative inertness to sorption and possible interactions with pond water and treatment chemicals. Special plastic-encased bolts and semisolid sealing tape were used to form watertight joints between the sidewall sections (fig. 4).

The sidewall sections were placed on 18-cm-thick, steel-reinforced, air-entrained concrete bases (figs. 3 and 4). The ponds are filled and emptied from ground level with portable equipment. Water-supply lines, drains, and pumping sumps would simplify filling and cleaning.

The excavation around the ponds was backfilled by compacting layers of soil no more than 20 cm thick. During backfilling the pond sidewalls buckled slightly, even though the ponds were full of water. This problem was alleviated by temporarily installing horizontal stiffener rings at the top of the sidewall sections.

After backfilling, reinforced concrete rings were poured around the upper portion of the ponds to stabilize the sidewalls and the underlying soil (figs. 1 and 3). The pond site is fenced to protect the public and the installation.

Automated Water-Quality Monitoring System

The water-quality monitoring system automatically measures and records temperature, pH, and dissolved oxygen by time of day. Additional measurements, such as specific conductance, depth, and concentration of specific ions, can be added to the system.

The monitor can record a maximum of 16 data points (channels) at time intervals of either 4, 8, 16, 32, 64, or 128 minutes. Printout of the 16 points requires only 30 seconds. The number of depth increments that can be monitored during a given period is limited, primarily, by the speed at which the sondes are moved from one depth to another.

A hoist speed of approximately 15 cm/min was

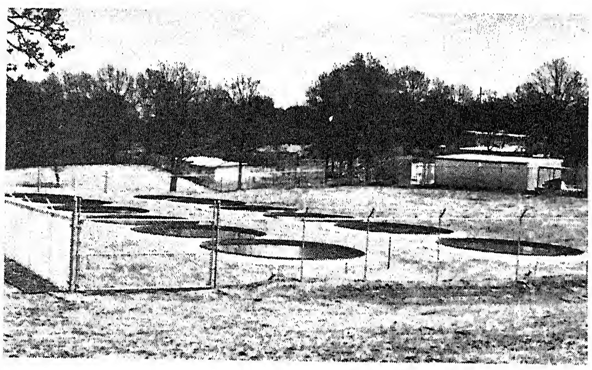

FIGURE 1.—Farm-pond system without monitors, 1974.

FIGURE 2.—Excavation, with ponds being leak-tested before backfill, 1974.

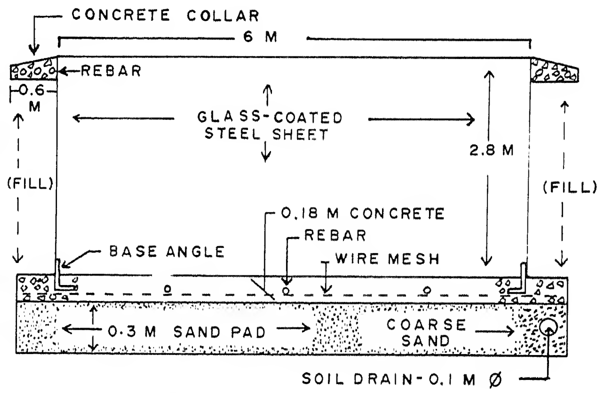

FIGURE 3.—Cross section of model pond showing primary components (not to scale).

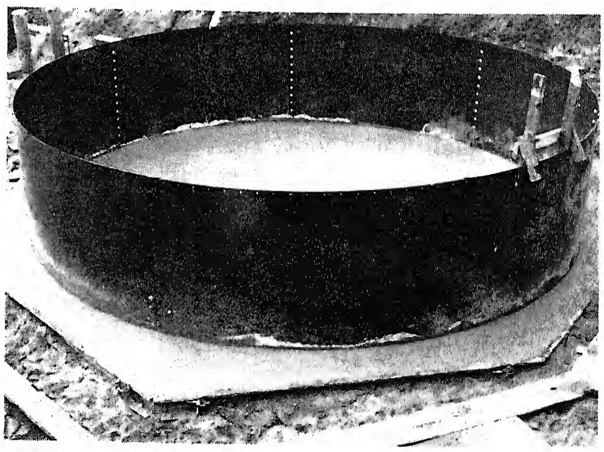

FIGURE 4.—Bottom pond section showing concrete base.

used for this installation in order to minimize disturbance of the water column by the sondes. Since hoist speed is a design option, the number of data points that can be recorded during a given period varies. The system described herein is operated at full capacity when monitoring temperature, dissolved oxygen, and pH from each of five sondes that are simultaneously repositioned every 16 minutes to one of seven depths. A total of 112 data points are recorded from the seven depths, and a full monitoring cycle, that is, a bottom readout to bottom readout, requires approximately 1.9 hours. Normal power supply for all components is 115 V a.c. The winch assembly, however, has a noninterruptable power supply of 12 V d.c. The block diagrams (fig. 5) give simplified relationships for subunits in the monitoring system.

Sondes (sensor packages).—A sonde located in each of five ponds contains sensors for temperature, pH, and dissolved oxygen. Water temperature is measured by a thermistor, pH by a combination electrode, and dissolved oxygen by a conventional polarographic electrode covered by a membrane. Figure 6 shows a sonde attached to the lower pulley.

Sonde cable support and drive.—Each sonde is supported by a cable running over a pulley and clamped to the main drive cable (fig. 6). The main drive cable raises or lowers all sondes simultaneously, and the movable block assembly with three pulleys allows positioning of the sondes throughout the length of the support trusses. The trusses were designed for strength, stability, and minimum interference with meteorological factors. The sonde sensor cables are attached to the top of each truss, with sufficient free cable to allow raising and lowering of the sondes. Figure 7 shows an overall view of the trusses and cable assembly, along with the portable catwalk used for serving the sondes.

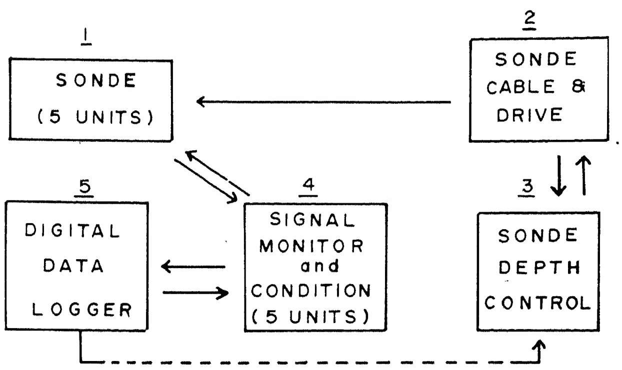

FIGURE 5.—Simplified function diagram for the automated water-quality monitoring system.

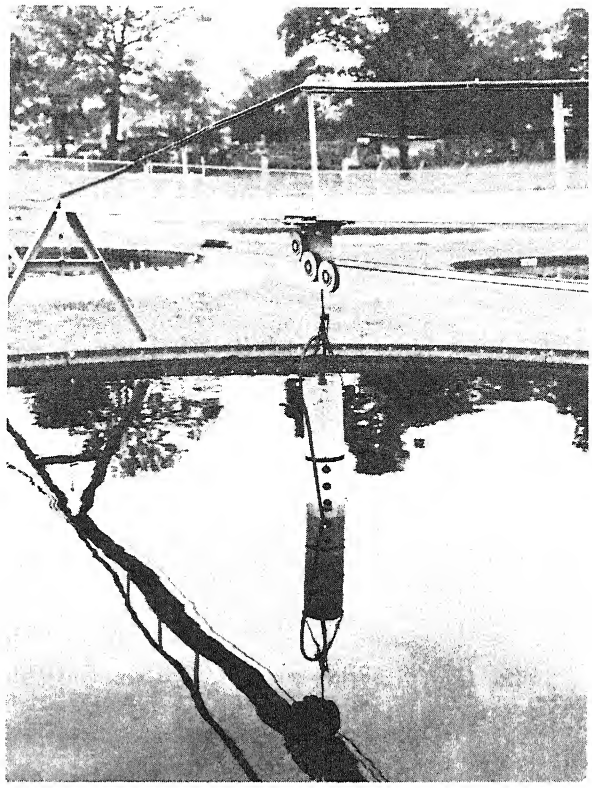

FIGURE 6.—Truss, cable support, and block assembly.

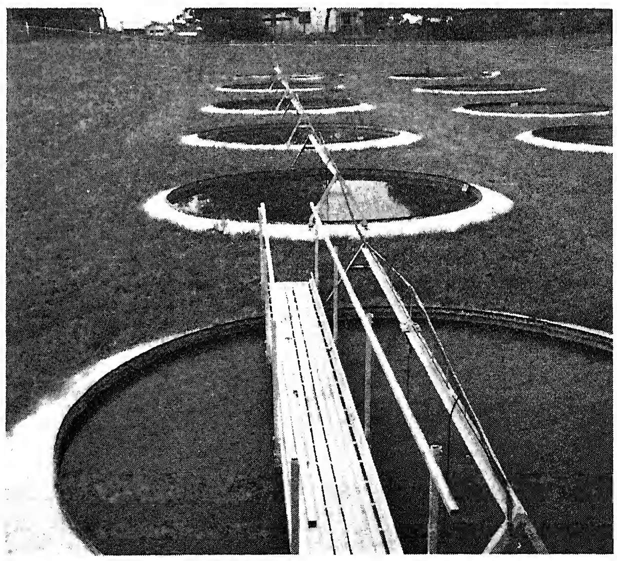

FIGURE 7.—Overall view of trusses and the sonde support assemblies.

Sonde hoist and depth controller.—Sonde depth intervals are controlled electronically by means of a winch that drives the main sonde cable (fig. 8). A 12-V-d.c. motor with gear reduction (fig. 8) drives the cable winch. The motor is reversible and has electromagnetic braking. A series of gears and belts drives a slow-moving timing disk (fig. 8). Holes in the timing disk pass light from stationary miniature bulbs to opposing stationary phototransistors (figs. 8 and 9). The phototransistors control the winch motor, which in turn drives the main cable for proper positioning of the sondes.

The winch power supply and electronic control unit (fig. 10) rectifies and delivers 12 V d.c. to the winch motor and charges the 12-V standby battery used in the noninterruptable power supply. This unit also indicates visually, and with an audible warning, when the system switches to battery power. Other functions are visual indicators for position of the depth control disk on the hoist and a manual override for cycling the hoist assembly.

The data logger activates the timing-disk controls when a readout is completed and starts the winch for the next depth. The position of the sondes is reproducible to ±3 mm, the accuracy being related to factors such as shrinkage or stretch in the drive cable and rigidity of the support assemblies.

Signal monitor and conditioner.—The sondes are coupled to individual signal monitors and conditioners by means of the sensor cables. These units display separate, continuous readouts for the sensors in each sonde. The data conditioned by each monitor are periodically recorded in digital form by the data logger.

Data logger.—The logger records incoming data from the monitors on paper or magnetic tape. It controls the sampling-time intervals and synchronizes readout with the sonde depth controller. The logger provides for manual override of the readout functions, allowing the user to calibrate and to test the readout. The logger can be interfaced with compatible data-processing systems.

Examples of data from the water-quality monitors.—The model ponds have not yet produced enough data for a detailed analysis of the diurnal changes in water quality. However, a simple example of available data will be discussed.

Forty hours of temperature and dissolved-oxygen (D. O.) data from two depths in pond No. 10, September 26, 27, and 28, 1975, are shown in figures 11 and 12. Solar noon was selected as an approximate midpoint for the curves because solar radiation and the potential for photosynthesis are generally greatest at that time of day. Cloud cover for the study period was generally

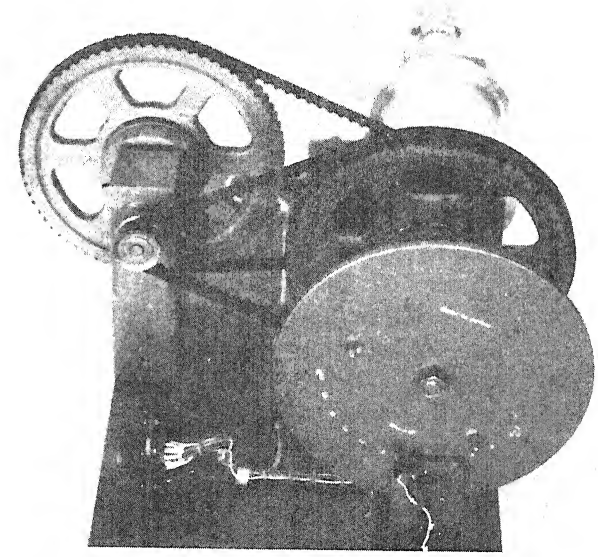

FIGURE 9.—Sonde hoist and depth controller, top-front view. Timing disk in the foreground controls winch operation and position of the sondes.

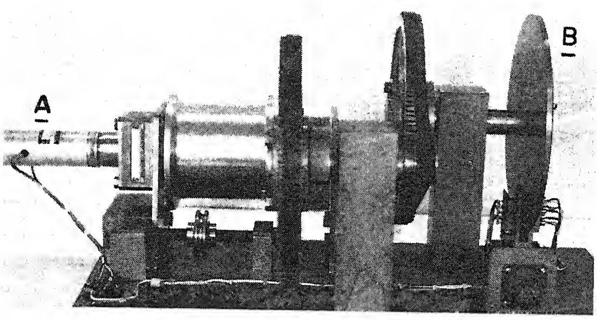

FIGURE 8.—Sonde hoist and depth controller, side view. *A*, Motor; *B*, timing disk.

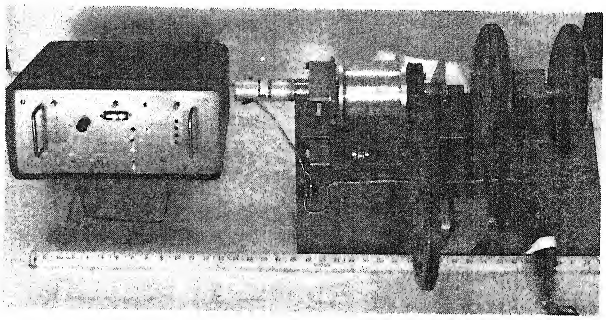

FIGURE 10.—Electronic control unit and power supply for sonde hoist assembly.

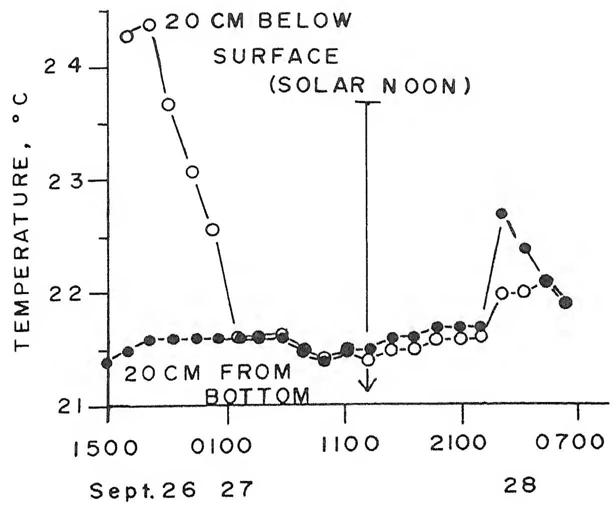

FIGURE 11.—Example of diurnal changes in water temperature, near the surface and near the bottom, pond No. 10, September 1975.

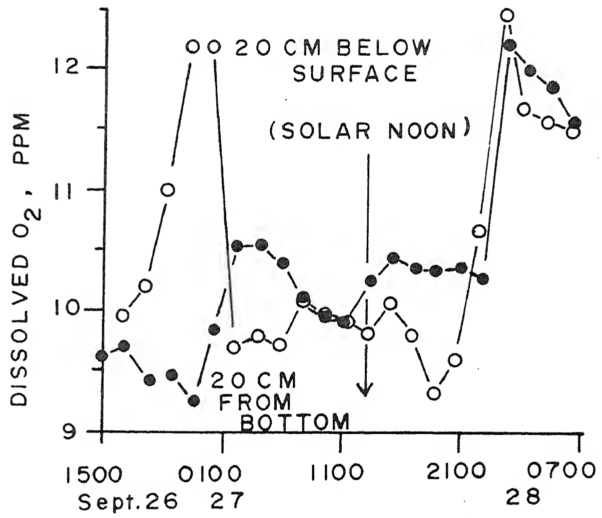

FIGURE 12.—Example of diurnal changes in dissolved oxygen, near the surface and near the bottom, pond No. 10, September 1975.

light and scattered, except for increased cloudiness from 1100 to 1700 hours on September 27. The pond was clear and contained a moderately heavy growth of rooted aquatic plants.

As would be predictable, the highest water temperature occurred near the pond surface at approximately 1830 hours, September 26 (fig. 11). Thereafter, cool winds and increased cloudiness prevented a marked rise in temperatures. An increase in temperature 20 cm above the bottom, near the end of the study, was an anomaly that cannot be explained by available data. However, the relatively uniform temperatures near the bottom are common to bodies of water that have large depth-to-surface ratios.

The highest D.O. content occurred between 2100 and 2400 hours, which is a time span similar to that for the highest temperatures (fig. 12). These results were predictable because, at that time of day, the water had been exposed to cumulative maximums of solar radiation and potential photosynthesis. Also, large losses of oxygen by respiration did not occur until around 2400 hours.

The lowest D.O. value near the pond bottom occurred at approximately 2230 hours, September 26, and the lowest value near the surface occurred at 1900 hours on September 27. The data available do not adequately explain the relatively low D.O. values recorded 20 cm below the surface between 1000 and 1900 hours, September 27. However, the low values may have been the result of reduced photosynthesis due to increased cloudiness, together with poor mixing of surface water with the relatively oxygen-rich deeper water.

Obviously, both water temperature and the rate of oxygen evolution from photosynthesis are highly responsive to changes in solar r
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